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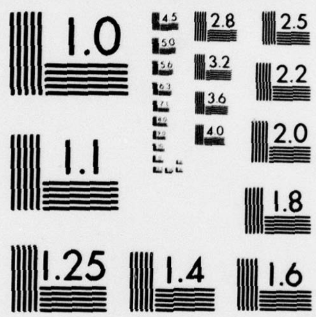

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Flat Panel Display Technology in Europe

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Dr. A. K. Nedoluha*
Dr. J. Silva**
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8 December 1978

*U.S. Army Research & Standardization Group
**Naval Ocean Systems Center, San Diego, CA.

UNITED STATES OF AMERICA

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This report is the result of a survey of Flat Panel Display technologies in early 1978. Countries visited included the United Kingdom, France and West Germany. Selected industrial and governmental research establishments were surveyed for developments in emissive (gas discharge, light emitting diode, electroluminescence) and subtractive (liquid crystal; electrophoretic, electrochromics) display technologies. Significant new applications of these flat panel technologies are also identified.

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C O N T E N T S

FLAT PANEL DISPLAY TECHNOLOGY IN EUROPE

BACKGROUND

In mid-1977 the Flat Panel Display was identified by this office as one element of the command and control technology base in which a significant amount of effort is underway at several European research centers. Since the US Navy has many applications of such technology (from aircraft instrumentation, shipboard command and control consoles, to large screen displays), a survey was conducted in mid-1978 to determine the state of technological development and to identify significant applications. Participating in this survey were representatives from the Naval Ocean Systems Center (NOSC), San Diego and the US Army Research and Standardization Group (USARSG), Europe.

In late 1976 NOSC started an exploratory development program to replace pushbutton-readout panels in shipboard command and control and consoles with Flat Panel Displays. In the longer term, there are also plans to scale-up such panels to satisfy plan-position-indicator (PPI) video display requirements, currently provided for by cathode-ray tubes (CRT). If this is not possible, a mixture of several Flat Panel Display technologies might be developed to satisfy all console display requirements.

The driving force behind applying Flat Panel technology to these consoles is to simplify hardware and command and control software design changes in response to changing operational requirements. Another significant benefit in the longer term will be an overall reduction in console size (required as the Navy moves toward smaller, lighter, higher-speed platforms).

Other potential applications of Flat Panel technology include automated status board and replacement of projection large-screen displays. Both of these (as well as the command consoles) are of interest to the US Army in their command center applications. The Army sponsors AC Electroluminescense work at Rockwell International, Westinghouse, and Aeroject Corporations in the US. Another US Army sponsored effort includes the light-emitting diode panel systems development at Litton Industries.

SCOPE

Because of the interest of the participants, this survey was limited to subdued ambient light applications such as those found in ships or command centers. High brightness technologies were only lightly covered and may be worth follow-up by technologists interested in such applications. Countries visited include the United Kingdom, West Germany and France. The Netherlands (Philips Company) also has a research program in this technology but was not covered for lack of time.

INTRODUCTION

The history of Flat Panel Display technology has been one of promising starts followed by slow transition to advanced development and production. In some cases technologies have been dropped altogether owing to other commitments for R&D money or problems in manufacturing such as low-yield or short life-expectancy. Direct current electroluminescent (DCEL) was dropped in the US, for example, because of short life expectancy experienced in prototypes.

Flat Panel Display technology can be divided into two basic types: emissive and subtractive. Emissive displays include gas discharge; light emitting diode (LED), electroluminescent, as well as CRTs. Gas discharge displays include AC and DC plasma panels (ACPP and DCPP) as well as more recent planar positive-column displays being developed by NHK (Japan Broadcoasting Corporation) in Japan and a similar development by AEG Telefunken in Germany. Within the category of subtractive displays the most important are liquid crystal (LCD), electrophoretics, and electrochromics. The latter two are in the early laboratory curiosity stage of development.

The progress of solid-state LEDs in replacing the incandescent and CRT technologies has been extremely slow, and it is certain they will never significantly impact the CRTs because of their low luminous efficiency (less than 5 lm/W).

Despite their ruggedness, reliability, and miniaturization, LEDs do not yet quite match backlighted liquid crystals in cost and luminous efficiency. If, however, the recent rate of improvement in quantum efficiency continues, they should be competitive in some applications as early as 1980. Some of the efforts observed so far seem to be toward trying to improve the quantum efficiency

of green and yellow LEDs over that of red. Since these two are much easier to view than red from a human factors standpoint, they may in fact make a significant long-term impact in severe environment, high-ambient light applications.

For flat panel displays, the strongest competitor to the LED yet produced, the LCD, has not reached its full technological potential. Further reductions in power requirements and increases in reliability are still possible as manufacturing methods are improved.

The two most common LCDs are dynamic scattering and twisted nematic structure. Since twisted nematic is the lowest voltage-power display available (1.5 - 10 V vs 15 - 25 V for the dynamic scattering) it is the most commonly used structure in battery-operated applications. Now that mean times-between-failures are in the region of 10 years and back lighting has been employed, LCDs have replaced LEDs in almost all such applications.

DCEL offers many advantages over other technologies including large-size, small-power and simple, low-cost drive circuitry. If efforts are successful to improve its life including improved manufacturing methods and better understanding of copper migration, DCEL may prove to be one of the best displays for medium alphanumeric panel applications (100 to several hundred characters).

Display formats are X-Y matrix alphanumerics, digital, fixed legend, or analog. In the X-Y format up to 66,00 elements (200 x 300 lines; 1250 characters) have been produced. The other formats are suitable for a wide variety of print styles and analog figures.

Alternating current electroluminescent (ACEL) displays consist of a film of zinc sulphide doped with copper or manganese or other metallic impurities enclosed between two conducting electrodes. The upper electrode is transparent allowing green, orange, or also now possibly blue, yellow, off-white, or red colors to be emitted. Brightness is low in these devices and is directly proportional to drive rms voltage and frequency. Typical times from full to half brightness are 1,000 to 10,000 hours (inversely proportional to the initial brightness). ACEL displays have also been developed by using thin film technologies, but to date production yields have been disappointing.

ACTIVITIES VISITED

The following sections provide the highlights of flat panel activity at the companies indicated. More information is available either from the authors of this report or from the companies themselves.

Royal Signals and Radar Establishment (RSRE), Malvern, UK

Contacts:

Dr. J. Kirton (Head, Display Section)
Dr. R. W. Sarginson (DCEL)
Dr. I. A. Shanks (LCD)
Dr. T. Hughes (Head, Radar Display Applications Section)
Mr. G. Watkin (PP Applications)

Activities:

RSRE has been developing DCEL technology for approximately nine years. The basic material used in their panels is Z_nS: Mn coated with Cu. Using pulsed DC techniques, they claim up to 5,000 hours mean time to failure (100-v drive potential with 1/200 duty cycle). In order to achieve further improvements in panel life, RSRE feel they must gain better understanding of copper migration. They plan to accomplish this by instrumenting panels with automatic test equipment (Hewlett Packard 9845) under varying voltage and current conditions. The DCEL panels produced by RSRE emit a pleasing yellow light which is broad enough in the spectrum also to give red and green colors by use of appropriate filters. Sizes produced to date are 2 in. x 4 in., 2 in. x 24 in., and 6 in. x 8 in. with up to 1,250 characters.

One of the first applications planned for RSRE-developed DCEL panels is for the telephone industry. Their requirement is for a small panel of 4 lines with 20 characters per line. This panel will be used in a display to provide operators with dialing codes, routing information, and basic telephone traffic data.

Other applications of the DCEL panels include analog displays for vehicle control information and a low resolution display for sector scan radar data.

RSRE has no development activities in plasma panel technologies but has an impressive application of that technology as a radar-data PPI. To date they have demonstrated range scaling, offset and cursor manipulation on a 512 x 512 element panel. To achieve the desired resolution of at least 100 lines/in., they would like to implement the same system using a 1024 x 1024 element panel.

However, with the limited shades of gray or brightness levels available, plasma panel technology seems best suited for display of more processed rather than raw radar-video information.

RSRE is also working with liquid crystals as display devices in applications such as portable low-power oscilloscopes, and spectrum analyzers. For projection display, a twisted nematic cell about 4 in.^{2} placed in front of a CRT can be controlled as a variable light filter switched in a sequential pattern producing red and green from the emitted light. Other shades such as yellow and orange can also be produced. This technique shows promise for color displays but is limited by the size of the cell and in certain applications by its viewing angle of approximatley ±20°.

LED activities at RSRE include--GaP (Green) 6-character module; GaP (red) 16-element linear array; GaP (red) 16-element curved array; GaP (yellow) 7-bar numeric; GaAsP (red) 2 x 60 element linear array; and GaAsP (red, yellow) 17-element circular array.

Plessey Microsystems, Towcester, UK

Contacts:

Dr. P. Hart (Head, Optoelectronics)
Dr. R. Hurdich (Optoelectronics)
Mr. J. C. Lewis

Activities:

The Plessey Opto-Electronics and Microwave Unit conducts research and development on microwave, infrared, and opto-electronic devices. In the opto-electronics area they have activities in red, green, and yellow LEDs, electrochromics and (in the past) electrophoretic displays. They are currently developing prototype LED arrays for optical scanners using 100 elements with 100-μm centers. Future developments planned in this area include a 100 x 200 diode matrix. The limit of such a LED diode matrix is basically the power consumption (which raises the sub-strate temperature and ultimately reduces the light output). High temperatures of 110 to 120°C reduce the light output by 20% after 500 hours.

Specific applications planned for these arrays include thermal imaging, line scanners, and data recording devices.

Future efforts planned include mounting integrated-circuit drivers onboard the LED array and improving modular design to allow for mosaic large-screen display construction.

GEC Hirst Research Centre, Wembley, UK

Contacts:

Prof. L. A. Thomas (Head Electrooptics Division)
Dr. D. K. Wickenden (LED Displays)
Mr. P. Burton
Mr. A. C. Greenham
Mr. P. C. Rundle

Activities:

The Display Department of the Electro-Optics Division at GEC is developing solid state electroluminescent displays based on DC electroluminescence in zinc sulphide powder phosphors and thin films for larger area applications. High resolution monolithic LED displays are also being developed using gallium arsenide phosphide emitting at 650 ± 20 nm. LED arrays of 15 x 15 mm are used in avionics head-up displays. Diode sizes of 40 x 40 μm with less than 10-μm separation are believed possible. Four thousand individual diodes have been fabricated into the 15 x 15 mm size display.

Demonstrated were DCEL panels capable of showing 480 characters in a 10 in. x 6 in. size. The resolution is about 40 lines/inch with connections on 50-thousandths centers, a 30:1 contrast ratio, and a brightness of 20-ft. Lamberts, operating over a temperature range of -40 to approximately +50°C. Currently GEC is planning to develop a 960-character panel with hybrid drive circuit technology. GEC feels that more development is needed with the thin film transistor (TFT) devices to improve efficiency and yield and is working in conjunction with RSRE on grading the phosphors to help predict the percent yield of the DCEL panels.

The current refresh rate of the line-addressed DCEL panels is approximately 200 lines without noticeable flicker, with a future requirement of about 240 lines on the 960-character panel. The construction technique used limits the element size or resolution to pixels of approximately 0.01 in.^{2} with 0.002-in. spacings.

The price of the 480-character panel with drive electronics is predicted to be $500.00 by 1981 (in 1977 dollars).

Standard Telecommunications Laboratories (International Telephone and Telegraph), Harlow, UK

Contacts:

Prof. C.H.L. Goodman (Chief Research Engineer)
Mr. M. Coupland (Head, Components)

Dr. J. Peters (Head, Displays)
Dr. J. H. Morrissy (LCD)

Activities:

The STL Display Divison has worked on ACPP in the past but have abandoned this area in favor of LC technology. The ACPP produced in 10 in. x 11 in. glass substrate with 524 conductor lines on a 0.016 in. pitch. A fabrication technique was used whereby a conductive liquid was combed across the surface of the glass substrate. Adequate resolution with this technique, however, was difficult to achieve, and the yield was considered unsatisfactory.

Present LC activities include developing touch-switch panels and 6 in. x 10 in. alphanumeric panels for military applications. In addition, STL has a significant materials effort aimed at better understanding the physics and chemistry of both smectic and twisted nematic LCs. Included in the nematic LC effort is the study of alignment of LC molecules, the measurement of the tilt angles and the examination of techniques for producing LC devices with repeatable characteristics.

STL also plans to have a 7-line multiplexing capability in smectic liquid LC alphanumeric displays within a year. This will require faster switching characteristics and a wider temperature range capability than is presently achieveable with the LC material they have developed to date. If past performance is any indication, STL will achieve the desired characteristics ahead of its competitors.

<u>Phosphor Products Co., Ltd., Poole, UK</u>

Contacts (not visited):

Dr. N. J. Werring
Dr. A. Vecht (also Thames Polytechnic)
Dr. P. Smith

Activities:

DCEL (pulsed--Past activities have been on 64, 256, 1250 character, alphanumeric and graphic displays (0.5% duty cycle, 5-15-μsec pulses, V24 interface, 120 V driving voltage divided equally between rows and columns, 25-40-ft. Lambert brightness, yellow-orange color, 40 line/in. resolution).

Current efforts are concentrated on 480-character prototype using low-power drive circuitry (2 W). One hundred line-per-inch resolution displays are also under development.

Ferranti, Ltd., Manchester, UK

Contacts (not visited):

Mr. F. Walters (Special Components Dept.)
Mr. S. Woodcock

Activities:

Plasma Panel (PP) (Pulsed DC)--Panels under development have the following characteristics: 7 x 5 matrix addressed, low DC maintaining voltage, 300:1 contrast ratio, 32 character (2 lines of 16) or 105 character (7 lines of 15), multicolor (orange, green), 10,000 hours operation to half-brightness, 10 in. x 3 in. size (30 cells/in.), high brightness, and military specification qualified.

Future efforts are being concentrated on phase addressing and red, blue color panels.

AEG Telefunken, Ulm, Germany

Dr. J. Bretting (Head, Tube R&D)
Mr. M. Schiekel (Displays)
Dr. Steinbeck (LCD)
Mr. Unbehaun (LCD Matrix Addressing)
Dr. Hellwig (PP)
Dr. Schwedes (PP)
Dr. Sussenbach
Dr. K. Schaffernicht (Head, Display Components)

Activities:

The AEG Telefunken Tubes and Sub-Assemblies Division produces electron tubes, subassemblies, tuners, microwave tubes, variable resistors, image converters, image intensifiers, GaAs cathodes, silicon targets, TV monitors, programmable switches for phase lock loops, yokes, color CRTs, magnetrons, and coaxial magnetrons for radar systems.

Telefunken also provides high resolution CRTs for airborne early warning and control system (AWACS) aircraft displays and is a second source for many US military CRTs.

Using birefringence techniques, Telefunken is developing LC cells to produce full color. Cells for projection display applications are 10-μm thick and have a 10- to 100-μsec switching time: 32 x 32 element cells were demonstrated in 1-in. squares.

Future plans include engineering development of 80 x 80 element cells and possibly 256 x 256 element cells in 1-in. squares.

Other Telefunken flat panel activities include pulsed DC plasma panels and a proprietary planar gas discharge display.

Siemens, Munich, Germany

Contacts:

Dr. A. Schauer (Head, Display Development)
Dr. C. Weyrich (LED and EL R&D)
Dr. D. Theis (LED and EL R&D)
Dr. H. E. Bergt (Optoelectronics)
Mr. K. Walter (LCD)
Dr. M. Kobale (PP)
Mr. H. Hacke (Technology)
Mr. K. Pöbl (Power tubes)
Mr. H. Hadersbeck (Technology)

Activities:

Siemens produces complete lines of optoelectronic semiconductors, LEDs, infrared emitting diodes (IRED), photodiodes, phototransistors, couplers, and photovoltaic cells. Research and development is continuing on the orange, yellow, and greenish-yellowish LEDs. More research, including substrate and new deposition techniques, is needed to increase the efficiency of the blue LEDs.

IREDs are also produced and research is ongoing in the 850-nm range. Monolithic diode arrays are produced in 2 mm by 2 mm packages containing 35 diodes and 4 green diodes for alignment of the package.

Siemens is looking at the AC thin-film electroluminescence with the black layer concept and is doing preliminary design work on thin-film transistor technology for addressing flat panels.

In the gas discharge area, Siemens is developing a flat quasi-CRT color display. This concept operates by extracting electrons from a gas discharge and accelerating them to high energy to excite conventional CRT phosphors. Scanning is accomplished by an X-Y matrix. The discharge of the gas require approximately 200 V and the acceleration voltage is between 3-5 kV. Color is accomplished by using the standard red, green, and blue CRT phosphors. The goal is an 8 1/2 x 11 in.-size color display.

The LC display under development at Siemens utilizes nematic cells, and an alphanumeric display 10 x 3 in. with 8 lines of 80 characters has been applied for. The panel uses back lighting to illuminate the display in low ambient light. Refreshing the display currently requires 30 to 40 msec/line, but improvements have been designed to decrease this response time.

Thomson-CSF, Corbeville, France

Contacts:

Dr. M. Hareng (Display Systems)
Mr. J. P. Hombrouck (Display Liaison)

Activities:

Thomson-CSF presented a smectic LC with a laser addressing scheme and a projection system to project the image onto a large screen. The smectic LC slide is approximately 2 cm x 2 cm, which is good for projection. The resolution is about 100 x 100 points per slide. This LC material operates at a temperature range of 30° to 35°C. and has a storage temperature range of 0° to 45°C. Further development is needed to speed up the response of the LC material. Color may also be possible by using more than one LC cell and optically combining or mixing the discrete color of each for projecting onto a screen.

Thomson-CSF, Grenoble, France

Contacts:

Dr. R. Agniel (Head, Electron Tube Production)
Mr. G. Moiroud (Image Tubes and Devices)
Mr. B. Courtan (PP, CRT)
Dr. M. Moulin (LCD R&D)
Mr. B. Driard (X-ray Image Intensifiers)

Activities:

Thomson-CSF, Grenoble, is producing planar ACPPs based on the Owens-Illinois panel technology. Panels of various sizes are produced and are available up to 512 x 512 pixels on 0.46-mm spacings.

The group is aiming at a one mega point plasma display for military applications. Life of these PPs is projected to better than 10,000 hours. Some color experiments have been performed, but this work has been terminated.

CONCLUSIONS

DCEL is clearly moving very rapidly toward production and offers an opportunity for developers of military displays to take advantage of a relatively low-cost alternative to the CRT for medium-sized alphanumeric applications. Large (6 in. x 10 in.) LC panel development is also a strong competitor for alphanumeric applications and has much lower voltage-power requirements making it attractive for battery-operated displays. LEDs are still not suitable for large scale displays but are a clear contender for imaging and small alphanumeric applications. PPs have potential in low-resolution radar displays and are currently being used in a number of alphanumeric applications. They are not however, a replacement for color CRTs. Planar positive-column displays appear to have the most potential of the emissive technologies to replace color CRTs, unless ACEL thin-film panels can be scaled-up with good production yields.